TITLE: ADDITIVE AND METHOD FOR FLUXING AND FLUIDIZING SLAGS IN FURNACES

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The invention relates generally to additives for and methods involving furnaces containing metallic charges, and in particular to additives and methods for fluxing and fluidizing slags.

2. Description of the Related Art

The coreless induction furnace is a refractory lined vessel with electrical current carrying coils surrounding the refractory crucible. A metallic charge consisting of scrap, pig iron and ferroalloys are typically melted in the vessel. When electrical current from the coils is passed through the charge, joule heating creates thermal energy that melts the charge. The magnetic currents that arise in the molten metal produce an intense stirring action, thus insuring a homogenous liquid. During the melting process, "slags" or non-metallics are generated from oxidation products, dirt, sand and other impurities from the scrap, erosion and wear of the refractory lining, oxidized ferroalloys, and other various sources. These non-metallics remain in the liquid metal as an emulsified “slag” until such time as they increase in size and buoyancy, coalesce and float on the liquid metal where they can be removed. Almost without exception, slags normally deposit in an area in the upper portion of the lining or crucible walls in a coreless induction furnace that is above the heating coils. These areas are at a much lower temperature than the center of the furnace walls. Slags will also deposit in areas midway down the crucible lining, where insufficient metal turbulence from magnetic stirring typically occurs.

Another type of induction melting furnace is the channel furnace. The difference between the two furnace types is principally in the placement of the induction coil and the metal bath. In coreless furnaces, the coil completely surrounds the crucible. In a channel furnace, a separate loop inductor is used which is attached to the main crucible which contains the major portion of the metal bath. A vertical channel furnace may be

considered a large bull ladle or crucible with and inductor attached to the bottom. Accumulations of slag over time will typically occur in the bottom inductor loop or throat area. When this happens, insufficient metal flow through the inductor loop hampers heat transfer and interferes with the melting operation. It is very difficult to remove accumulations of slag from the inductor loop or throat area. Often, the furnace will have to be taken out of operation and a new inductor installed. Typically, inductor life may be as long as 18 months. However, if slag build up occurs, the useful life may be reduced to only a few months.

Pressure pour furnaces are sealed holding furnaces normally blanketed with a nitrogen atmosphere and having an induction coil attached to the bottom of the furnace. Pressure pour furnaces are designed to hold liquid metal at a constant temperature for periods of 1 to 3 days. When the pressure pour furnace is pressurized, a stream of molten metal exits the vessel for mold filling. These furnaces are not designed to melt metal. Circulation of liquid metal through the inductor throat or loop provides the heating of liquid metal to keep a constant temperature in the furnace. Build-up of slag often occurs in the inductor loop and throat areas. When this happens, the inductor will have to be replaced, since it is extremely difficult to remove the built up slag.

Slags and dross from the above mentioned electric melting methods, if not totally removed at the melting furnace, will be transferred to the metal pouring ladles. Since the walls of the pouring ladle are much cooler than the furnace refractory lining, build up of slag on the ladle sidewalls is usually inevitable. This build-up must constantly be removed and a significant amount of labor is usually expended in keeping pouring ladles clean. Failure to do so may result in casting scrap from slag inclusions.

Other areas where slag and dross can become a problem are in the production of ductile iron using the flow-through process. The flow-through process utilizes a refractory lined reaction chamber. The reaction chamber is filled with a nodulizing alloy such as magnesium ferrosilicon. Slag and dross build-up often occur in the reaction flow-through chamber. This slag build up tends to clog the opening of the chamber as well as the exit or tapping hole.

During the operation of electric induction melting furnaces, non-metallics are produced from the various sources described earlier. Depending on the specific

process being used and the type of iron or steel being melted, the composition of the slag will vary. The cleanliness of the metallic charge, often consisting of sand-encrusted gates and risers from the casting process or rust and dirt encrusted scrap, has a significant effect on the type of slag formed during the melting operation. Additional oxides or nonmetallic compounds also can be formed when metal is treated with materials to remove impurities or to change the chemistry of the system. Because these oxides are not soluble in iron, they float around in the metal as an emulsion. This emulsion remains if the molten iron is agitated, such as in the case of the magnetic stirring inherent in induction melting, until the particle size of the non-metallic increase to the point where buoyancy effect countervail the stirring action.

When floatation effects become great enough, non-metallics rise to the surface of the molten metal and agglomerate as a slag. The use of fluxes accelerates this process.

In some instances, oxides may have a lower melting point than the prevailing metal temperature, and a liquid slag is formed. In other cases, where the oxides have a higher melting point than the metal temperature, a dry, solid slag is formed.

When a previously formed slag contacts the refractory lining of a furnace wall, treatment vessel, ladle lining, or other portions of the holding vessels that are colder than the melting point of the slag, the slag is cooled below its freezing point and adheres to the refractory lining. This adhering material is called "build-up". High melting point slags are especially prone to promoting this build-up condition. If not removed as it forms or prevented from forming initially, the efficiency of the metal handling system is reduced. Build-up composition will be more complex if the slag reacts with the refractory employed in the melting furnace.

Additives to the melting process that insure that slags have a melting point below the coldest temperature in the system, are called fluxes. This action of additives or fluxes prevents the material from freezing on the refractory surfaces. The use of a flux will usually ensure floatation of the emulsion of oxides and reduce the melting point of the slag to below the coldest temperature encountered in the melting, treatment and handling system to minimize slag build-up.

Fluxes lower the melting temperature of slags. If the slag formed is viscous and has a great affinity to adhere to the furnace sidewalls, the use of a fluidizing flux will reduce this tendency. The type of flux required will depend upon the specific operation. Great care must be exercised when using a flux, since overzealous use may actually result in undesirable reactions with the furnace refractory.

Three important physical characteristics of slags are melting point, viscosity and wetting ability. Generally, slag is required to remain liquid at temperatures likely to be encountered during melting, metal treatment, or metal handling. Slag is required to be fluid for ease of removal from the melting furnace, to promote good slagging reactions and to prevent build-up in channel furnace throats and loops as well as coreless furnace sidewalls. In electric furnaces and pressure pour furnaces, slags are required to have a high interfacial surface tension to prevent refractory attack and to facilitate slag remove from the surface of the molten metal.

Fluxes are compounds that are added to molten irons and steels principally to decrease the fusion or melting temperature of the slag. Fluxes also affect the surface tension and viscosity of the slag. Lastly, fluxes allow for the coalescence of low melting point slag droplets that may become emulsified in the liquid metal bath of high frequency induction furnaces. Iron and steel fluxes containing alkali elements also aid in sulfur reduction and removal.

Flux additions provide a non-metallic liquid to absorb the extraneous impurities; they assist in producing a liquid slag consisting of absorbed non-metallics, providing the slag is sufficiently liquid at existing furnace operating temperatures. Fluxes will also modify a slag so that it will separate readily from the iron and permit ready removal of the non-metallics. The non-metallic material to be removed by a flux addition is primarily silica and metal oxides; these materials usually exhibit a relatively high melting point. With their high melting point, these non-metallic materials form a viscous or a pasty constituent in electric melting furnaces.

The viscous non-metallics exert several bad effects on coreless, channel and pressure pour furnaces An example of such behavior is slag formation that adheres to the furnace and/or inductor walls and interferes with melting. This decreases efficiency. Many of the materials in the slag are acidic in character, which opposes absorption of

sulfur into the slags so that an attempt is made to keep the flux basic to neutralize this acidity. Limestone is a popular material used for this purpose.

Fluorspar, a calcium fluoride mineral (CaF_2), is a powerful fluxing agent that is commonly used in small proportions along with limestone to improve slag fluidity. Fluorspar, while effective, has certain serious disadvantages. Specifically, fluorspar is a very aggressive flux and works extremely well in integrated steel mill as well as cupola operations. The overzealous addition of fluorspar or fluorspar containing fluxes to electric melting furnaces will result in severe lining erosion. In addition, another important disadvantage in connection with the use of fluorspar is its release of active fluorides as a gas upon decomposition in the furnace. The highly reactive properties of these gaseous fluorides are well known. In connection with those electric melting operations that have emission control systems using fiberglass bags as a filtration device, the gaseous fluorides attack the glass fibers.

From the foregoing it will be appreciated that shortcomings exist in the current fluxing methods.

SUMMARY OF THE INVENTION

It is one object of this invention to provide a fluorspar-free flux that has all the metallurgical advantages of a fluorspar-bearing type fluidizing flux.

It is another object of this invention to provide a flux that produces good fluxing action, but yet not be corrosive to refractory linings.

Another object of this invention is to provide a flux which can be used in connection with operations using fiberglass bags in the bag houses of the electric melting emission control systems where fluorspar types of flux materials can have a deleterious effect on the life and performance of the glass filters.

According to an aspect of the invention, an additive for fluxing and fluidizing slags in molten metal includes calcium carbonate; magnesium carbonate; alumina; silica; and sodium oxide.

According to another aspect of the invention, a method of fluxing and fluidizing slags in molten metal includes adding a flux composition to the metal; wherein the

fluxing composition includes calcium carbonate; magnesium carbonate; alumina; silica; and sodium oxide.

To the accomplishment of the foregoing and related ends, the invention comprises the features hereinafter fully described and particularly pointed out in the claims. The following description sets forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention.

DETAILED DESCRIPTION

A method of fluxing and fluidizing the slag formed in electric melting furnaces by adding a fluxing material including by weight from 8.0 to 28.7% $CaCO_3$ (calcium carbonate or limestone), from 0 to 18.5% $MgCO_3$ (magnesium carbonate), from 3.6 to 18.0% Al_2O_3 (alumina), from 1.4 to 7.1% SiO_2 (silica), in the form of a complex aluminosilicate, and from 19.4 to 46.4% Na_2O (sodium oxide), in the form of soda ash (sodium carbonate). With regard to the Na_2O, the amount of soda ash may be 33.2 to 79.5% by weight. For coreless induction, vertical channel and pressure pour furnaces, with either basic or neutral linings, the flux may be used in amounts ranging from about 0.01 to 0.10% by weight, based upon the metal charge. Even using flux in amounts less than 0.01% by weight may be useful. In addition, flux may be added in larger amounts, for example up to about 0.75% by weight. The flux serves to improve and reduce the fluidity and viscosity of the slag, reduce the melting temperature, remove and coalesce emulsified slag particles, soften build-up on furnace sidewalls and inductor throats, without emitting gases harmful to the atmosphere.

According to one specific example, a flux formulation was prepared from approximately 53.5 parts by weight of soda ash (Na_2CO_3) (corresponding to 30.7 parts by weight of sodium oxide (Na_2O)), 15.5 parts of calcium carbonate ($CaCO_3$), 13.0 parts of magnesium carbonate ($MgCO_3$), 11.65 parts of an alumina (Al_2O_3), 5.0 parts of silica (SiO_2), and 0.75 parts of a polyethylene glycol internal release agent. It will be appreciated that a variety of different suitable grades of limestone may be employed to

provide calcium carbonate and/or magnesium carbonate. These constituents in particulate form were thoroughly admixed and then compressed using a rotary briquetting press. Tablets weighting approximately 0.25 ounces (7 grams), 0.5 ounces (14 grams), and 1.5 ounces (28 grams) were produced. The resulting briquettes or tablets (agglomerations) were structurally sound and could withstand continued dropping from a height of 10 feet over a dozen times without breaking. The tablets were very strong, and able to withstand the vigors of shipping and adding to mechanized feeding systems in typical electric furnace charging systems. Thus this form of the invention offers several advantages. This same mixture, without the addition of the polyglycol internal release agent may also be bonded with water and pressed into larger shapes. Briquettes bonded with water can be allowed to set in a controlled moisture atmosphere for 24 hours to provide a structurally sound briquette. The same loose mixture, as a powder, can be put into small bags and the bag can be simply tossed into a ladle. The bags may be any of a variety of suitable materials, such as paper or poly propylene. Because of dust and fume associated with adding a loose material to a hot furnace or ladle, it may be desirable to palletize the product.

A "powder," as the term is used herein, may have a size range from +100 mesh to a size that could pass through a 0.25 screen opening. An "agglomeration," as the term is used herein, includes anything bigger than a powder.

The addition of between 0.01 to 0.75% by weight of the metallic charge has been sufficient to prevent slag build up on furnace walls and keep inductor loops and throats open. In one instance, the addition of 0.25 lbs (114 grams) of flux to 1,500 lbs (680 kg) of metallic charge in a coreless induction furnace was sufficient to prevent build-up of slag on the sidewalls. The furnace ran much cleaner and the lower viscosity slag which was produced was easily removed. Since almost all of the emulsified slag was removed, the pouring ladles also ran much cleaner. This fluoride free flux served to reduce the viscosity of the slag and coalesce minute slag particles so that the furnace lining remained free from slag build-up.

The amount of the flux used is not critical and may range for basic or neutral operation, from about 0.01 to 0.10%, more particularly from about 0.025 to 0.075%, and even more particularly from 0.035 to 0.075% by weight, as a percentage of the weight

of the metal charge. As stated above, more broadly the amount of flux may be from about 0.01 to 0.75% by weight. Should the flux addition be too low there simply not enough flux in the electric furnace or ladle to react with the nonmetallics that are present. An excessively high flux addition should be avoided for economic reasons and also to prevent attack of the electric furnace refractory. Dirty, sand encrusted scrap and shredded steel charges laden with rust will require more flux while cleaner scrap and casting returns require less. For cleaning ladles, the amount of flux that needs to be added may be in the range of 0.01 to 0.05%, based on the weight of molten metal in the pouring ladle. Alternatively, the particular range may be from about 0.025 to 0.10%, and may more particularly be from about 0.05 to 0.075%. In addition, a greater or lesser amount of flux may be used, as discussed above.

It is preferred to make the flux additions as bricks, briquettes, pellets or other agglomerated form for purposes of convenience and control of the quantity of addition and to minimize stack losses. However, other suitable techniques of incorporating the flux with the charge may be used.

The resulting flux constituents will dissociate upon exposure to metal casting temperatures, and react to form calcium silicon aluminates and sodium aluminum silicates. The reaction products provide superior fluxing results without the disadvantage of other fluxes described heretofore.

From a quantitative standpoint, the particular flux briquettes prepared as aforementioned contain about 16% $CaCO_3$, about 13% $MgCO_3$, about 12% Al_2O_3, about 53% Na_2CO_3, about 5.0% SiO_2, and about 1% by weight an internal release agent.

The fluxing composition may contain $CaCO_3$, Al_2O_3, $MgCO_3$, Na_2O, and SiO_2. The $CaCO_3$ may vary by weight from about 8.0 to 28.7%, may vary by weight from about 8.0 to 22.0%, may vary by weight from about 8.0 to 18.3%, and may vary by weight from about 12 to 16%. The Al_2O_3 may vary by weight from about 3.6 to 18.0%, and may vary by weight from about 8 to 14%. The $MgCO_3$ may vary by weight from about 0 to 18.5%, may vary by weight from about 6.7 to 18.5%, and may vary by weight from about 11.5 to 15%. The Na_2O may vary by weight from about 19.4 to 46.4%, and may vary by weight from about 26.1 to 31.9%. The SiO_2 may vary by weight from about

1.4 to 7.1%, and may vary by weight from about 4.5 to 6.5%. It may be unnecessary to make any deliberate addition of SiO_2, as this may be otherwise found in the charge and/or with the other constituents. Polyglycol or another suitable release agent may be added for use as a binder. Other suitable binders, such as suitable gums or natural or synthetic resins, may be employed.

The flux of the present invention is environmentally superior to fluorspar since fluorspar based fluxes generate gaseous fluorides compounds which are released at high temperatures.

Flux trials at a foundry that melts all types of gray, ductile and steel in a coreless induction furnace have been very successful. Addition rates are 1.5 lbs per ton of molten metal (0.075%). The refractory on the sidewalls of the furnace are clean, with substantially no build-up. In addition, since the fluidized slag now is removed from the furnace, the pouring ladles now remain free and clear of slag. The labor associated with maintaining the furnace and ladles has been drastically minimized.

Additional flux trials at a ductile iron foundry that has a pressure pour holding furnace have also been successful. Prior to use of the flux, the foundry was experiencing significantly reduced inductor life. The throats of the inductor loop would start to clog almost immediately after installation.

Other trials at a foundry having slag problems in a 12-ton coreless induction furnace have also been successful. For these trials, 12 lbs of flux were initially added to 23,000 lbs of the charge (0.052%). This level of addition greatly reduced the viscosity of the slag but made the slag difficult to skim off the surface of the metal. Reducing the addition rate to 6 pounds per 23,000 lb. (0.026%) charge increased the viscosity slightly and no problems were encountered with slag removal. The walls of the induction furnace now stay clean and the carryover of slag into the ladles has been eliminated. The ladles now also stay clean.

Trials at still another foundry with a 1-ton coreless induction furnace have also shown significant reduction in furnace sidewall build-up. This foundry added 0.25 pounds of the flux to 1,500 lbs of the metallic charge (0.016%). This level of flux addition eliminated the slag build-up from the furnace walls that the foundry was experiencing.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (*i.e.*, that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.